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Segmentation of Doppler Carotid Ultrasound Image using Morphological Method and Classification by Neural Network

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Abstract— In the recent times, image segmentation plays a critical role in medical study for taking individual decisions by physicians. This technique attempts to estimate the structure of lumen and plague segmentation on the transverse view of B-mode ultrasound images of common carotid artery (CCA). The proposed method segments both the lumen and plague, whereas only the lumen is segmented in the conventional methods. The lumen contours are segmented using self-adaptive histogram equalization, non-linear filtering, sobel edge detector and morphology methods. Plaque in the blood vessel is examined by automatic detection using Fuzzy C-Means (FCM) filtering and canny edge detector methods. The significant benefit of the proposed method has been numerically validated on real time image data from RCT'S (Philips HDI 5000 Ultrasound Scanner) and results show that the proposed method performs in a better way when compared to existing techniques. The proposed method is simulated using MATLAB (2013a).

Keywords— Anisotrophic filter, Segmentation, Lumen, Plague, FCM filtering , Classification, Neural Networks.

1. INTRODUCTION

According to the World Health Association (WHO) cardiovascular disease (CVD) causes an estimated 29% of death worldwide for a total of about 17.1 million people. In the United States alone, CVD results in direct and indirect healthcare costs and loss of productivity amounting to $274 billion annually[9].The parameters measurement and the analysis of clinical data are important to the cerebro vascular and cardiovascular pathologies diagnosis; and have attracted significant attention amongst the health and science community .Ultrasound (US) has been employed as the gold standard for non-invasive [2], versatile technique with no known side effects and the equipment used for ultrasonic scanning is also small and inexpensive. Arterial alterations are major factors of cardiovascular diseases [10] . The arterial system can be considered as an elastic chamber, represents the blood volume in systole and delivers a suppressed, almost constant flow to the capillaries in diastole. Patients with the common carotid artery (CCA) need to know the risk factors for circulation problems that can lead to blockages in the heart, which can lead to morbidity and mortality. Segmentation and identification of CCA inner and outer contours in B-mode US images is an important step in evaluating arterial disease severity. Therefore, the aim of the proposed work is to segment the lumen and plaque contours of CCA automatically, and reduce the physician's workload to outline the boundaries manually.

2. PROPOSED METHOD FOR SEGMENTATION

The database image is acquired from the scanner RCT'S (Philips HDI 5000 Ultrasound Scanner) and the real time images are collected from Johnson scan center and Q-scans which shows the transversal view of CCA (Common Carotid Artery).The acquired image contains speckle noise which degrades the quality of the image. Hence to remove the speckle noise, preprocessing is done in order to enhance the quality of the image. The image is pre-processed using Aniostrophic diffusion filter and converted into polar coordinates image using polar transformation. The block diagram of proposed segmentation technique is shown in the figure 1.

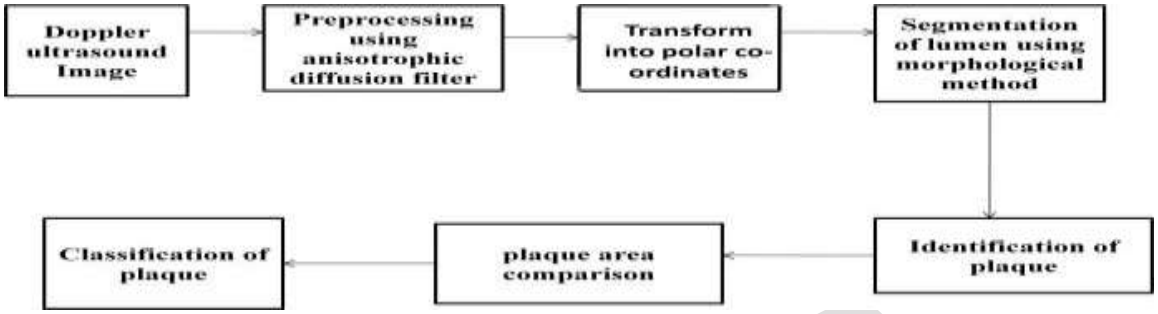

Fig 1: Block diagram of proposed method

2.1 Anisotrophic Diffusion Filter

Anisotrophic diffusion filter is a non-linear technique for removing the speckle noise. The knowledge of noise pattern and power spectrum is not needed, which is the advantage over the other filters. In the proposed method this filter is used to remove the noise without blurring the edges and it also sharpen the edges .The result of pre-processing using anisotrophic diffusion filter used to enhance the ultrasound scanned image is shown in figure 2.

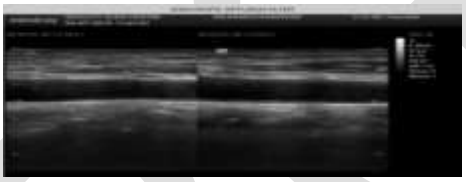

Fig 2: Pre-processing using Anisotrophic Diffusion Filter

2.2 Polar Transformation

The cartesian coordinate does not provide the clear knowledge of plaque. Whereas, polar coordinates provides the accurate occurrence of plaque. Hence, cartesian to polar converter is used in the proposed method to view the image clearly. The polar transformation image is shown figure 3.

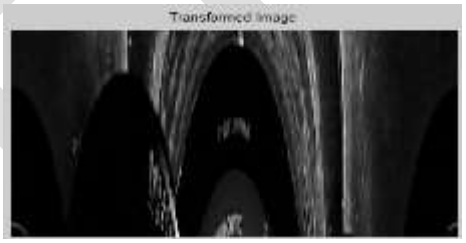

Fig 3: Polar Transformed Image

3. LUMEN SEGMENTATION

After the polar transformation , the lumen segmentation [11][12] is done by the following steps
Step 1: Self-adaptive histogram equalization to improve the contrast of US image
Step 2: Non-linear filtering to reduce speckle noise
Step 3: Sobel Edge Detection
Step 4: A closed lumen wall region segmentation using morphological operation
Step 5: Concrete contour extraction of the lumen wall.

3.1 Self adaptive Histogram Equalization

There are disadvantages in the image histogram equalization algorithm(i,e)when it maps the pixels in the same gray level to the same new gray level, which results in unsatisfactory performance of the processed image, especially when the picture has many pixels distributed at low gray levels. To resolve this problem, an improved self-adaptive image histogram equalization algorithm [3] is used in the proposed method. This method extends the gray levels to ensure the pixel distribute at large-scale gray levels and increase the brightness of the resulting image. The figure 4 shows the enhancement of image using self adaptive histogram equalisation technique .to make the details to view easily. The result of Self-adaptive histogram equalization is shown in the figure 4.

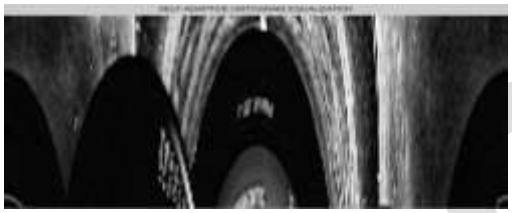

Fig 4: Self-Adaptive Histogram Equalization

3.2 Sobel Edge Detection

Besides the various methods available for edge detection operator the proposed methods uses the sobel edge detector which gives the sharp edges and used to find the interpolated points between the pixels. The output of the sobel edge detection is shown in figure 5. The magnitude of the gradient is calculated using the equation 1.

$$G = \sqrt{G_x^{\,2} + G_y^{\,2}} \qquad (1)$$

An approximate magnitude can be calculated using the equation 2.

$$|G| = |G_X| + |G_Y| \qquad (2)$$

Fig 5: Sobel Edge Detection

3.3 Closed Lumen Wall Segmentation

The closed lumen wall is segmented by using morphological operation in the proposed method, which separates the lumen structure from the carotid image. These operations uses a structuring element based on the shape of the structure of the lumen. At each pixel position, a specified logical operation is performed between the structuring element and the underlying binary image. The binary result of the logical operation is stored in the output image. The effect being created depends upon the size and content of the structuring element and the nature of the logical operation. If the structuring element is perfectly fit on the binary image, then the logical operation is performed; else it does not perform any logical operation into the resultant binary image pixel.

3.4 Standard Morphological Operations

The standard binary operation contains erosion and dilation. Dilation is the process in which the binary image is expanded from its original shape (i.e.) grows or thickens. In the proposed method erosion operation is used [1][3] , in order to shrink or thin the image which can be out looked clearly. The details of the image is smaller than the structuring element are being filtered from the image; it gives the function as same as "line filter". The output of the erosion operation is shown in figure 6.

Fig 6: Eroded image

3.5 Segmented Lumen

The proposed lumen segmentation is carried out by morphological operation [13] to see any fatty material present outside the lumen wall. The plaque segmented in the lumen may be in any shape. Hence in the proposed method, the structuring element is chosen as square shape [4]. The segmented lumen is shown in figure 7.

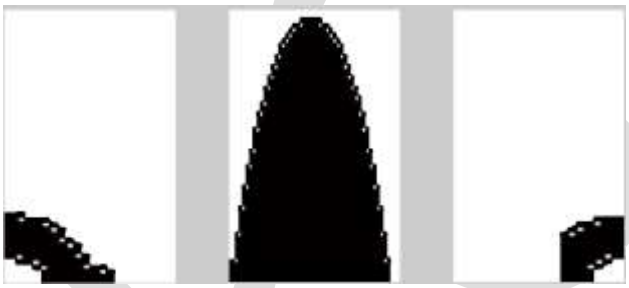

Fig 7: Segmented Lumen

4. PLAQUE SEGMENTATION

A Plaque is an unwanted fatty material presented inside the blood vessel. A piece of plaque or a blood clot also can break away from the wall of the carotid artery. The plaque can travel through the bloodstream and get struck in one of the brain arteries. This can lead to block the blood flow in the artery and cause a stroke. The plaque segmentation [11][12] in the proposed method contains canny edge detection process, FCM filtering [8] with hard and soft plague segmentation process .

4.1 Canny Edge Detection

Apart from the various edge detection methods, canny edge detection is used in the proposed method. It significantly reduces the amount of data and filters the unwanted information, while preserving the important structural properties in an image. The output of the canny edge detection is shown in figure 8.

Fig 8: Canny Edge Detector

4.2 FCM Filtering

Fuzzy c-means has been a very important tool for image processing by clustering the objects in an image.FCM filtering is used in the proposed method to increase the brightness of the image which enhances the plaque area [5]. The result of the FCM filtering is shown in figure.9.

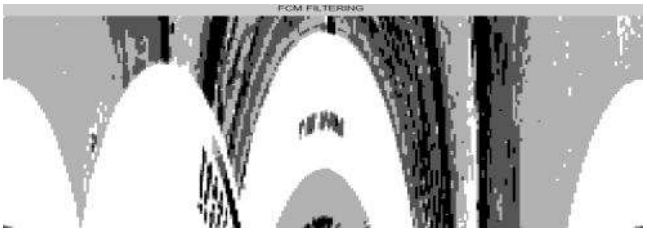

Fig 9: FCM filtering

4.3 Hard and Soft Plaque Segmentation

Hard plaques are mostly calcium and scar tissue, whereas soft plaques contain most of the cholesterol material which has a consistency of tooth paste. Soft and hard plaques are detected in the proposed method to segment the affected are in the blood vessel. The output of the hard and soft plaque segmentation are shown in figure 2.10(a),(b).

Figure 10(a) Hard Plaque (b) Soft Plaque

4.5 Area Affected By Plaque

The area affected by the plaque is segmented which is shown in Figure 2.11

Fig 11: Affected Area

4.6 Plaque Area Calculation

The plaque area is calculated from the segmented plaque region. The threshold value can be calculated from the resultant image of the affected area using the gray level threshold function in MATLAB. Based on that threshold value the gray image is converted into binary image such that the image contains only binary zero's and one's. It is easy to separate the plaque area from the background pixels and the area calculation of plaque region. The area calculation formula shown in equation 3

$$\textbf{Plaque Area} \quad S = \sqrt{P} * 0.264mm^2 \quad (3)$$

5 CLASSIFICATION USING NEURAL NETWORK

Multi layer Feed forward back propagation network [7] is used in the propsed method for classification. The Training method used here is Resilient Back propagation. Feature Extraction is one of the most important step to classify the image as normal and abnormal. After the segmentation, feature (area of plague), can be calculated and classification can be done using Neural Network .

The results of calculated plaque area of 6 sample images are listed in the table 1.

Table 1 : Plague Area Calculation for Various Images

IMAGE	AREA (mm)	RESULT
IM 1	0.24	Normal
IM 2	0	Normal
IM 3	0.02	Normal
IM 4	0.07	Normal
IM 5	4.976	Abnormal
IM 6	6.654	Abnormal

In the proposed method as per literature survey the plague area greater than one is classified as 'Abnormal' using neural network and plague area less than one is classified as 'Normal' one. The results classified as normal and abnormal using neural network is shown in the figure 12.

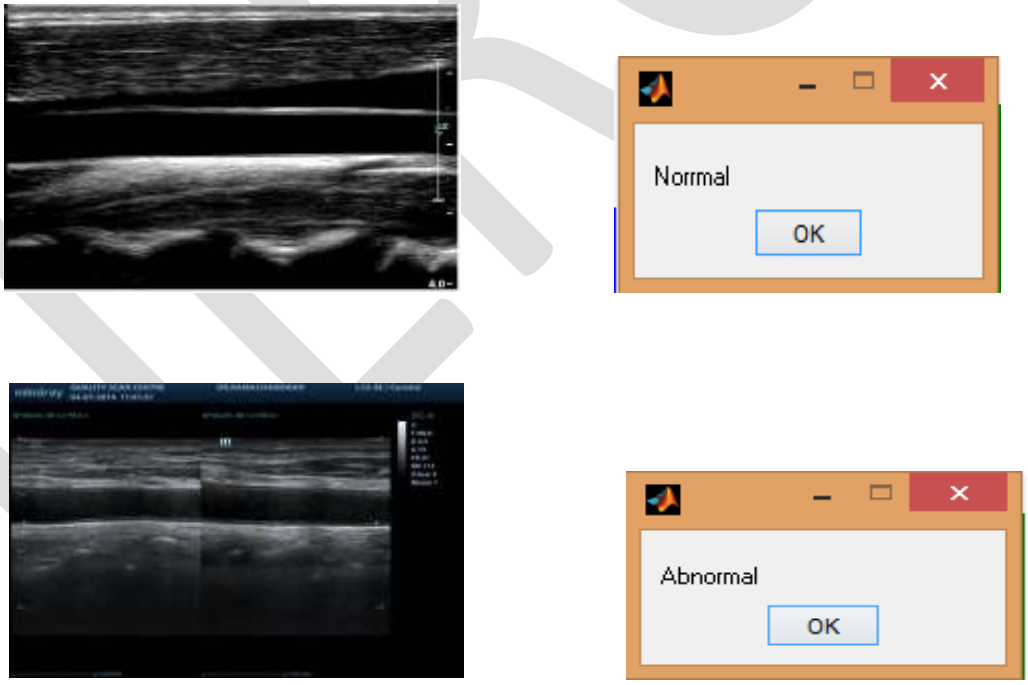

Fig 12: Classification using neural network.

6. CONCLUSION

In the proposed method, an automatic segmentation technique for extracting carotid lumen and plaque area for 2D transverse view of ultrasound image is implemented using simulated tool. Two different techniques are used in preprocessing and the results are simulated. The proposed method is based on mathematical morphology and FCM filtering and classified using

neural network classifier. This method could save the physician's invaluable time to take care of the atherosclerotic patients towards the prevention of cardiovascular disease which is expected to be reason for 50% of death rate in India by 2014. In future the lumen and plaque can be segmented by using watershed algorithm and Spoke's ellipse algorithm.

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